1.3 Measurement variables: recommendations and order of precedence

Measurement variables required for flux measurement and analysis and for the use of flux data are listed below. Here, the variables are ranked as “essential”, “A,” “B,” or “C,” according to their order of precedence, mainly in terms of CO_2 flux measurement. Lower-ranked variables may be adopted or rejected based on the purpose of the study.

1.3.1 Variables essential for eddy covariance flux measurement (turbulence fluctuation method)

The following variables are essential for energy or CO_2 flux measurement.

1) Three-dimensional wind velocity fluctuation
2) Sonic virtual temperature fluctuation
3) Water vapor (density or volumetric mixing ratio) fluctuation
4) CO_2 (density or volumetric mixing ratio) fluctuation
5) Air temperature, humidity, and atmospheric pressure (These must be measured by sensors that have slow but stable responses)

1.3.2 Micrometeorological and hydrological variables

In addition to the eddy covariance technique, the mean value of the following micrometeorological and hydrological variables can be measured.

Micrometeorological and hydrological variables are used for flux analysis. In particular, variables that are ranked as “essential” in this section are necessary for checking the quality and interpolation of CO_2 flux and of the amount of net ecosystem CO_2 exchange.

Radiation

Although it is best to measure upward and downward shortwave, longwave, and photosynthetically active radiations (PARs) as well as radiations over and under the canopy, measurement of radiation over the canopy takes priority over the other measurements (Table 1.3-1). Net radiation can be calculated by subtracting the sum of the upward short and long-wave radiations from that of the downward short and long-wave radiations. Moreover, a spectroradiometer or radiation meter for a certain frequency domain can be set up for ground-based verification using remote sensing technology.

Basic micrometeorological variables

Air temperature, humidity, wind velocity, and wind direction at about the same height as the point of the eddy covariance measurement over the canopy are indispensable.
Measurements of the amount of precipitation and of the shallow ground temperature are also required.

Profile (vertical distribution) measurement variables

Table 1.3-2 shows the profile (vertical distribution) measurement variables.

To calculate CO_2 storage change, the CO_2 profile needs to be measured; the CO_2 storage change is required for the calculation of the net ecosystem CO_2 exchange (NEE) of the plant community. The radiation (solar radiation and PAR) profile can be measured for a detailed investigation of the photoenvironment of the complicated forest crown layer.

Table 1.3-1 Variables required for flux measurement (radiation).

	Over the canopy		**Under the canopy**	
	Downward	**Upward**	**Downward**	**Upward**
Shortwave radiation	essential	essential	A	A
Longwave radiation	A	A	B	B
Photosynthetically active radiation	essential	essential	A	A
Spectroradiation (radiation of different wavelengths)	B	B	C	C
Net radiation	B	B	C	C

Table 1.3-2 Profile (vertical distribution) measurement variables.

Measurement variables	**Rank**
Air temperature profile	B
Humidity profile	B
Wind velocity profile	B
Soil temperature profile	A
PAR profile	B
CO_2 density profile	A

Other

Measurement variables can be adopted or rejected according to the characteristics of the observation site and the purpose of the study (Table 1.3-3).

Table 1.3-3 Other measurement variables.

Measurement variables	Rank
Atmospheric pressure	A
Soil heat flux	A
Temperature of canopy surface, leaf surface temperature	C
Snow depth	A
Snow water equivalent	C
Water quality of precipitation	C
Soil moisture profile	A
Groundwater level and quality	C
Amount of fog drip (precipitation resulting from thick fog condensing on leaves)	C
Water level, water temperature, and amount of irrigation water	B
Stem temperature: Required to calculate the amount of heat stored in stems and to estimate stem respiratory volume	C
Amount of water, snow, or other moisture adhering to the canopy	C
Sap flow velocity or sap flow rate	C
Amount of rainfall interception (throughfall, stemflow) and associated water quality	C
Amount of runoff and associated water quality	C

1.3.3 Structure and basic characteristics of a plant canopy

It often requires a great deal of effort to investigate the structure and basic characteristics of an ecosystem, especially in a forest of tall trees. For measurement variables that display only small secular changes, data obtained from a single observation conducted during the measurement period is enough to help clarify the condition of the site.

To determine the carbon balance of the agricultural ecosystem, it is necessary to measure the biomass and carbon content in different parts of each crop in order to estimate the amount of agricultural product removed from the study site at harvest. The influx of carbon accompanying the application of organic materials such as compost and the outflow of carbon accompanying the burning of crop residues are essential measurement variables when those management methods are used (Table 1.3-4).

Table 1.3-4 Measurement variables of an ecosystem.

Measurement variable	**Rank**
LAI (Seasonal variation of vertical integrated value)	A
LAI (Vertical distribution profile)	B
Phenology observation	B
Canopy surface image	B
Hemispherical image from forest floor	C
Amount of litterfall	C
Soil survey	B
Inventory to estimate above-ground biomass	A
Survey of tree roots	C
Amount of agricultural products removed at harvest	A
Amount of organic materials applied (e.g., compost)	A
Amount of crop residues burnt in the field	A
Leaf photosynthetic characteristics	B
Nitrogen content of tree leaves	B